Kovarikia, a New Scorpion Genus from California, USA (Scorpiones: Vaejovidae)

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Kovarikia, a new scorpion genus from California, USA (Scorpiones: Vaejovidae)

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http://zoobank.org/urn:lsid:zoobank.org:pub:EC2A7F7F-C182-4C76-9321-16E695226BC4

Summary

Genus *Kovarikia*, **gen. nov.** (Scorpiones: Vaejovidae) is described from southern California, USA. The genus is composed of three species previously placed in *Pseudouroctonus*: *Kovarikia williamsi* (Gertsch et Soleglad, 1972), **comb. nov.** (type species), *K. bogerti* (Gertsch et Soleglad, 1972), **comb. nov.**, and *K. angelena* (Gertsch et Soleglad, 1972), **comb. nov**. Major diagnostic characters of *Kovarikia* are its unique neobothriotaxy found on the ventral surface of the pedipalp chelae, the occurrence of a secondary lamellar hook on the hemispermatophore, a crescent-shaped mating plug barb, the presence of a secondary exteromedian (EM_c) carina on the pedipalp patella, and a swollen telson vesicle with anterior vesicular ridges.

Introduction

Gertsch & Soleglad (1972) described no less than 20 species and subspecies in the family Vaejovidae, 13 of which were placed in the genus *Uroctonus* Thorell. Since Gertsch and Soleglad's original work, the taxonomy of these species, as well as new species described in later years, has gone through several changes. Stahnke (1974) moved most of the species placed in *Uroctonus* into genus *Vaejovis* and created the genus *Pseudouroctonus* for the sole species *P. reddelli*. Williams & Savary (1991) defined the genus *Uroctonites* comprised of a new species *U. giulianii* and three of the *Pseudouroctonus* species originally defined by Gertsch & Soleglad (1972). Stockwell (1992) reversed most of Stahnke's taxonomic acts by moving the species Stahnke placed in *Vaejovis* into *Pseudouroctonus*. Since its inception, five other species have also been placed in *Pseudouroctonus*, *P. minimus* (Kraepelin, 1911), *P. glimmei* Hjelle, 1972, *P. sprousei* Francke et Savary, 2006, *P. savvasi* Francke, 2009, and *P. peccatum* Tate et al., 2013. In this contribution, we move three *Pseudouroctonus* spp. originally placed in *Uroctonus* by Gertsch & Soleglad (1972) to a new genus, *Kovarikia.*

The new genus is defined primarily by unique trichobothrial patterns and by the structure of the hemispermatophore and mating plug. Soleglad & Fet (2008: 38) first recognized the uniqueness of this genus and wrote:

"....The secondary hook may be of taxonomic importance since it is clear that some of these species are closely related, especially *P. williamsi*, *P. bogerti*, and *P. angelenus*, which also share other unique characters (e.g., neobothriotaxy of the chela, see Fig. 13). ...".

The analysis presented in this paper confirms the above suspicions that trichobothria and the hemispermatophore are important taxonomic characters. Herein, we describe and illustrate major diagnostic characters for *Kovarikia*, including trichobothrial configurations, hemispermatophore and mating plug structure, development of pedipalp patellar carinae, and the telson morphology. A key to the three species and a map showing their known distribution is provided. The Appendix provides complete trichobothrial patterns for the three species of *Kovarikia* and the hemispermatophore and mating plug of *K. bogerti*. This contribution is part of our ongoing revision of genera *Pseudouroctonus* and *Uroctonites*, which currently contain 22 species and probably several additional, unrecognized genera.
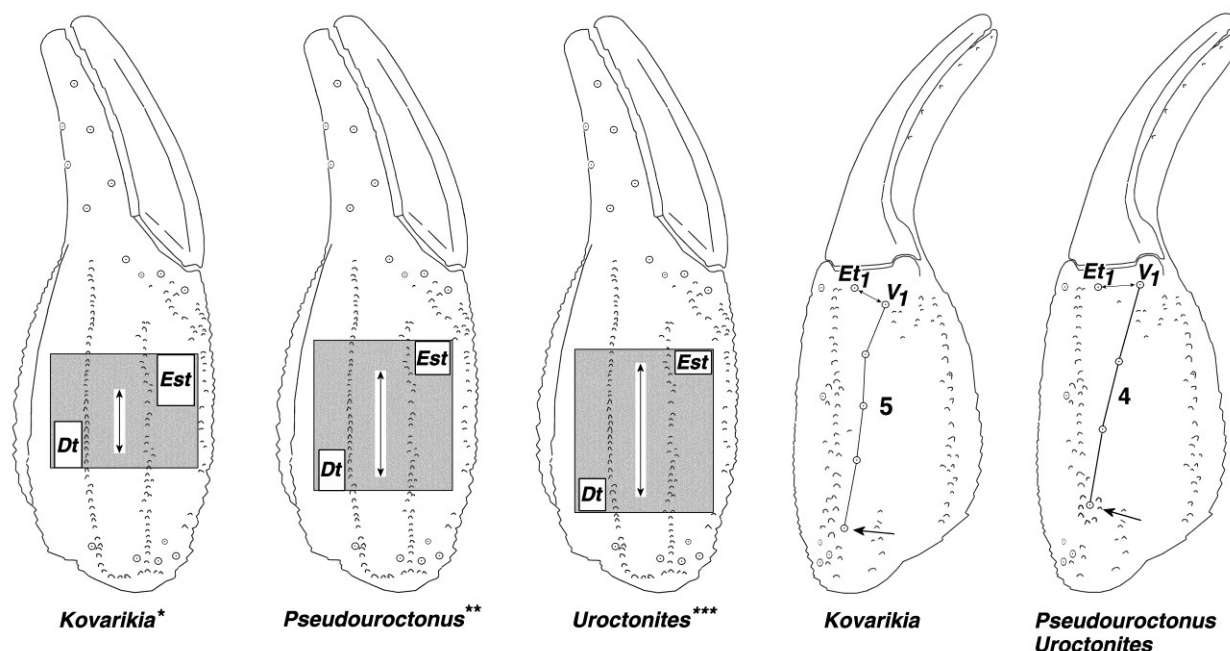
Figure 1: Diagnostic trichobothria positional characters of genus *Kovarikia*, **gen. nov. Left-Center.** Close proximity of trichobothria *Dt* and *Est*, their distance less than that of *Dt* from the palm base. **Right.** *Et₁|V₁* line slants proximally. Terminal ventral trichobothrium not located in a depression nor in the ventroexternal carina (*VI*). Note, rectangles indicated by *Est* and *Dt* show the vertical range of the two trichobothria and the vertical double-headed arrow indicates the average position of trichobothria *Dt* and *Est*. * includes *Pseudouroctonus iviei* and *P. glimmei*. ** excludes *Pseudouroctonus iviei*, *P. glimmei*, and *P. lindsayi*. *** includes *P. lindsayi*.

Methods and Material

Abbreviations

List of depositories: BH, Personal collection of Blaine Hébert, California, USA; GL, Personal collection of Graeme Lowe, Philadelphia, Pennsylvania, USA; MES, Personal collection of Michael E. Soleglad, Winchester, California, USA; MRG, Personal collection of Matthew R. Graham, Connecticut, USA; RA, Personal collection of Richard F. Ayrey, Flagstaff, Arizona, USA.

Terminology and conventions

The systematics adhered to in this paper follows the classification as established in Fet & Soleglad (2005) and as modified by Soleglad & Fet (2008). Terminology describing trichobothria adheres to that described in Vachon (1974), pedipalp chelal finger dentition follows that described and illustrated in Soleglad & Sissom (2001), that of the sternum follows Soleglad & Fet (2003a), the metasomal and pedipalp carination, and leg tarsus armature follows Soleglad & Fet (2003b), and the hemispermatophore follows Soleglad & Fet (2008). Note, in this presentation "mating plug" refers to the plug located in a hemispermatophore, sometimes re-ferred to as "hemi-mating plug". Mean morphometric values are presented in parentheses and sample sizes are presented in brackets.

Map generation software package

Map was generated by Earth Explorer 6.1, with positional and altitude data compiled through Google Maps.

Material Examined

Kovarikia angelena: *USA, California*: Ventura Co., Yerba Buena Canyon, 34.0833°, -118.95°, 19 October 1991, 1 ♂, leg. B. Hébert (BH).

Kovarikia bogerti: *USA, California*: San Diego Co., Oak Canyon, Old Mission Dam, 32.84°, -117.0422°, 11 March 1977, leg. S.C. Johnson & W.R. Icenogle, 1 ♀ (GL); San Diego Co., Palomar Canyon, 33.3029°, -116.8807°, June 2013, 1 ♂, 1 ♀, leg. M.R. Graham (MRG).

Kovarikia williamsi: *USA, California*: San Diego Co., Santa Ysabel Preserve, 33.10°, -116.70°, 1 ♂, 2 ♀, leg. USGS pitfall trap (MES); San Diego Co., W of Hwy 15, next to Lawrence Welk Resort, 33.2275°, -117.1505°, 2005, 1 ♀, leg. M.R. Graham & J.R. Ingoldt (MRG);

San Diego Co., Mission Gorge, 32.8390°, -116.9534°, 2010, 1 ♂, 4 ♀, leg. M.R. Graham (MRG).

Structure Analysis

We describe in detail the primary diagnostic characters of genus *Kovarikia*. This includes neobothriotaxy, positional configurations of orthobothriotaxic trichobothria, the hemispermatophore and its mating plug, pedipalp patella carinal development, and the telson. Other partially diagnostic characters are also briefly discussed including the carapace, metasomal segments, chelicerae, and pectinal tooth count ranges.

Trichobothria

Neobothriotaxy. Neobothriotaxy is quite rare in the family Vaejovidae. It is found in four genera involving only 11 species (out of currently described 23 genera and 190 species): (1) monotypic smeringurine genus *Paravaejovis* exhibits variable neobothriotaxy in the ventral series of the chela, with V numbers ranging from 11 to 14 (Soleglad & Sissom, 2001: tab. 3), (2) vaejovine genus *Franckeus* (six species) possesses a single accessory trichobothrium in the patellar *esb* series (a synapomorphy), (3) smeringurine species *Paruroctonus ammonastes* exhibits a single accessory trichobothrium in the patellar *et* series, and (4) *Kovarikia* **gen. nov.** (three species) has one to two accessory trichobothria in the chelal ventral series.

Neobothriotaxy in *Kovarikia* is clearly a synapomorphy for this genus (see Figs. A-1–A-3 in the Appendix for the complete trichobothrial patterns of all three species). Based on the female holotype of *K. bogerti* illustrated by Gertsch & Soleglad (1972: figs. 70–71) and examination of material in this study (thirteen specimens), the number of ventral trichobothria found on the chela ranges from 4 to 6 (5.040) [25]. Only one chela of *K. bogerti* exhibited four ventral trichobothria, otherwise the neobothriotaxy was quite consistent. The female holotype specimen from Riverside County has six ventral trichobothria.

Orthobothriotaxy. In the ongoing cladistic study of genera *Pseudouroctonus* and *Uroctonites* (a total of 22 species), we have compiled complete trichobothrial patterns for 19 species, three of which are shown in this paper (Appendix Figs. A-1–A-3). Based on detailed comparisons of these patterns we found several positional differences in the orthobothriotaxic trichobothria that further distinguishes the genus *Kovarikia* from *Pseudouroctonus* and *Uroctonites* (see Figure 1).

Angling of trichobothria Et_1 and V_1: In *Kovarikia*, V_1 is located more proximal to the base of the movable finger than Et_1, so a line drawn between Et_1 and V_1 slants proximally (Fig. 1). This is apparent in all three species of *Kovarikia* and not matched in any of the other 16 trichobothrial patterns studied, where the $Et_1|V_1$ line is essentially parallel to the base of the movable finger.

Relative position of *Dt* and *Est* trichobothria: in *Kovarikia*, trichobothrium *Est* is located somewhat proximally, close to the palm midpoint; and *Dt* is positioned more distally than in other species of *Pseudouroctonus* and *Uroctonites*, not especially close to the palm base. Consequently, based on the combination of these two dislocations, the distance between *Dt* and *Est* is shorter than the distance between *Dt* and the palm base. In general, *Dt* in genus *Pseudouroctonus*, and especially *Uroctonites*, is located proximally and likewise, *Est* is more distally placed, thus the distance between these two trichobothria approaches or exceeds the distance between *Dt* and the palm base. Note, only species *P. iviei* (Gertsch et Soleglad, 1972) and *P. glimmei* (Hjelle, 1972) match *Kovarikia* in this character, suggesting a possible sister clade (see hemispermatophore discussion below). We calculated the morphometric ratio $Est|Dt / Dt|$Palm_base for 19 species divided into the following groupings:

Kovarikia + (*P. iviei* + *P. glimmei*): 0.171–0.695 (0.436) [5]
Pseudouroctonus: 0.700–1.071 (0.855) [10]
Uroctonites+*P. lindsayi*: 1.022–1.673 (1.335) [4]

Note, *Pseudouroctonus* in the above excludes the three species included with the other two groupings. *P. lindsayi* (Gertsch et Soleglad, 1972) is grouped with *Uroctonites* based on similarities in their hemispermatophore structure. In *Kovarikia*, species *K. bogerti* and *K. angelena* exhibit the smallest ratio values, 0.171 and 0.286, respectively. We also conducted variance analysis (ANOVA) for all three groups which resulted in p-values <0.001.

Position of the V_4 trichobothrium: in *Kovarikia*, the terminal ventral trichobothrium of the chela is positioned on the ventral surface, not in a depression on the ventroexternal (*V1*) carina. In all other species of *Pseudouroctonus* examined, the terminal ventral trichobothrium is located in a depression close to or on the *V1* carina.

Hemispermatophore

Secondary lamellar hook. Another diagnostic character of genus *Kovarikia* is the presence of a secondary lamellar hook on the hemispermatophore (Fig. 2). This important structure was reported and illustrated for the first time by Williams & Savary (1991: figs. 26–29) for *K. bogerti*, *K. angelena*, *P. iviei* and *P. glimmei*. Soleglad & Fet (2008: figs. 40, 67, 88) illustrated the secondary lamellar hook for *K. williamsi* and established the term "secondary lamellar hook" to contrast it with the primary lamellar hook common in many vaejovids.
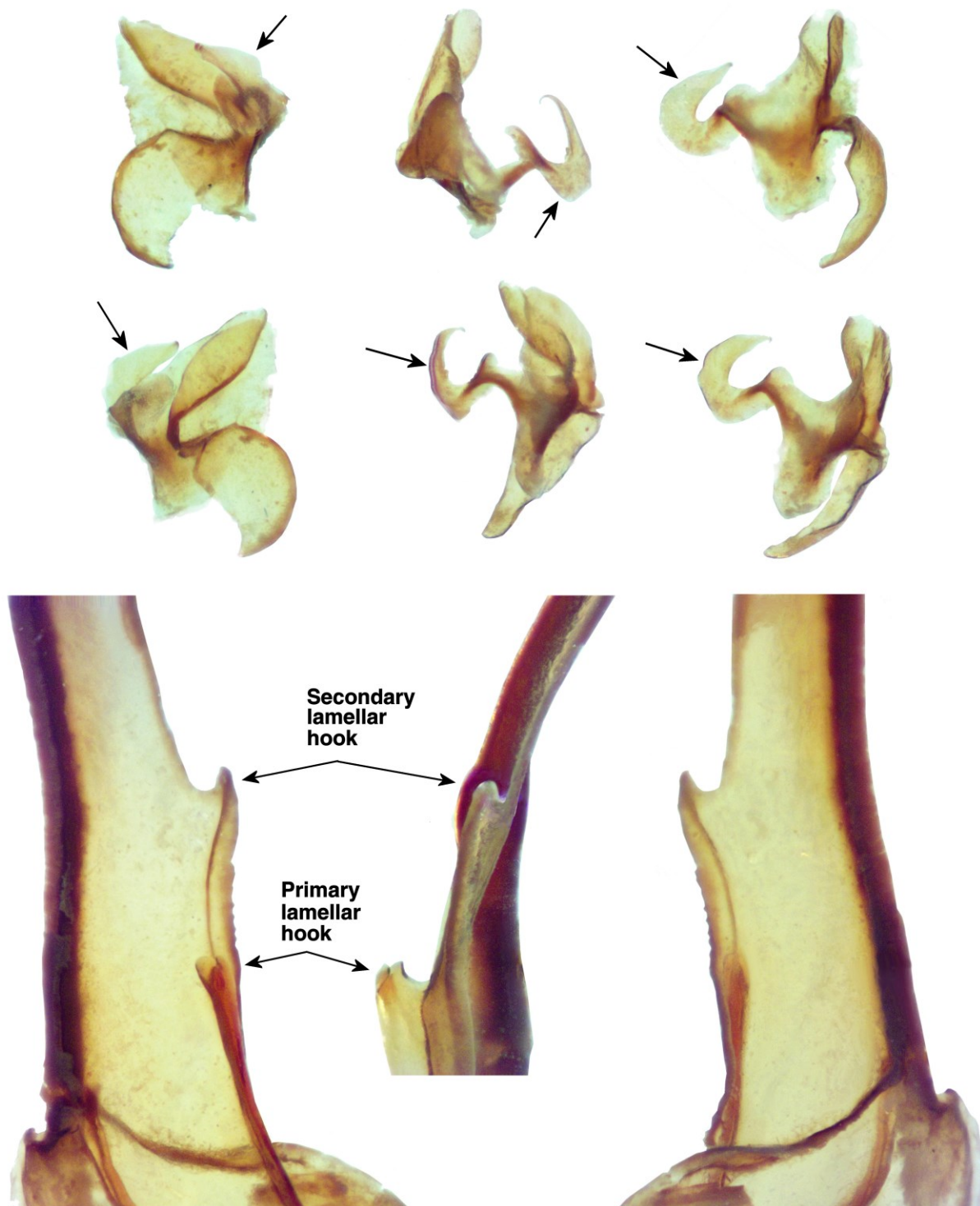
Figure 2: Right hemispermatophore showing the primary and secondary lamellar hooks, and mating plug (photographed submerged in alcohol). *Kovarikia williamsi*, male, Santa Ysabel Preserve, San Diego Co., California, USA. **Bottom.** Lamellar hooks, dorsal, internal, and ventral views. The primary and secondary lamellar hooks are indicated. **Top.** Mating plug, internal, dorsal, and ventral views (top row), external, and two ventral views (bottom row). Note, the mating plug in the ventral and dorsal views is oriented the same as it would be embedded in the hemispermatophore median area. The "crescent-shaped" barb with its smooth edge is indicated by an arrow.
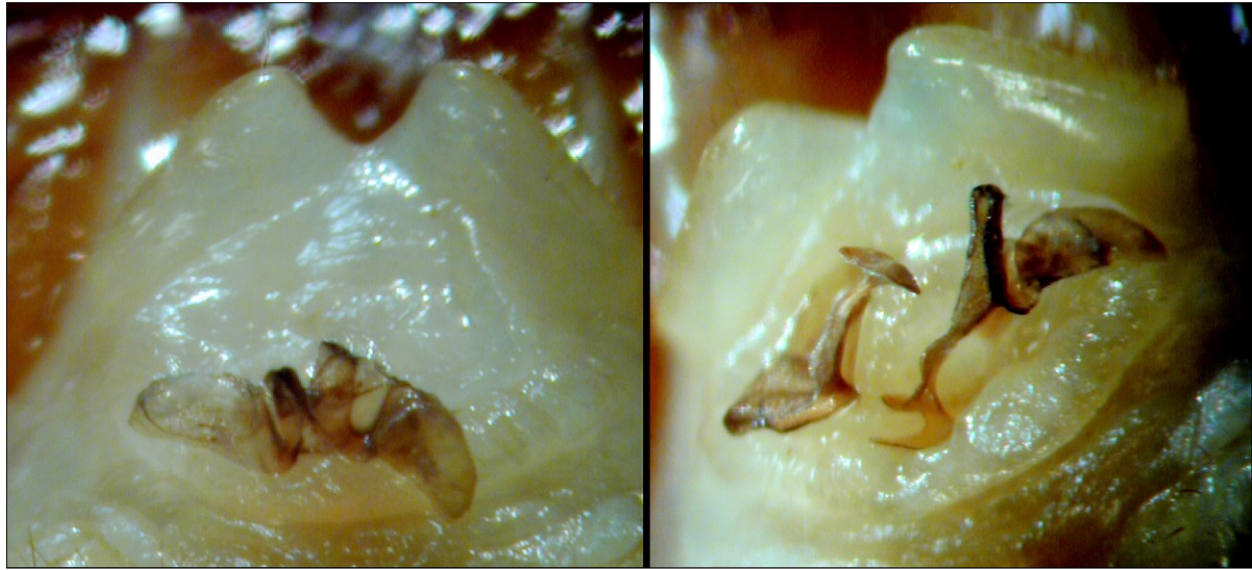
Figure 3: Genital operculum and mating plugs of *Kovarikia williamsi*, female, Santa Ysabel Preserve, San Diego Co., California, USA. **Left.** In this specimen (collected in a pitfall trap) post-insemination spermatophore mating plugs were found protruding from the genital aperture, only the plug bases are visible. **Right.** Mating plugs are extracted from genital aperture exposing the barbs. After (in part) Soleglad & Fet (2008: figs. 29–30).

The secondary lamellar hook is located distal of the primary lamellar hook, approximately equidistant between the lamina terminus and the ventral trough edge. Though the hook is not bifurcated it does extend somewhat from the thin internal edge of the lamina. Its dorsal edge originates from the primary lamellar hook which is formed from the dorsal trough edge. The secondary hook's ventral edge is formed from the lamina's thin edge and terminates at the base of the ventral trough edge. The primary lamellar hook is structured as in other *Pseudouroctonus* species, and as well as in many other species in subfamily Vaejovinae. It originates entirely from the dorsal trough edge, is bifurcated, and protrudes on the dorsal side.

Interestingly, the secondary lamellar hook is also found on two *Pseudouroctonus* species from northern California, *P. iviei* and *P. glimmei*, the most northern species in *Pseudouroctonus*. We have information on the hemispermatophore for 17 of the 18 species defined in *Pseudouroctonus* and *Kovarikia*; it is unknown only for *P. chicano* from north-central Mexico. Therefore, since the five species that have a secondary lamellar hook are all found in California, it is unlikely that *P. chicano* also has this unique structure. Based on this assumption, we hypothesize that the secondary lamellar hook represents a synapomorphy for the clade *Kovarikia* + (*P. iviei* + *P. glimmei*).

In published illustrations of hemispermatophores, five species of *Vaejovis* exhibit a modest, *obtuse marginal protrusion* (OMP) located above the primary lamellar hook: *Vaejovis rossmani* and *Vaejovis monticola* (Sissom, 1989: figs. 76–79), *Vaejovis chisos* (Jarvis

et al., 2004: figs. 1–2), *Vaejovis sprousei* (González et al., 2004: figs. 1–2), and *Vaejovis coalcoman* (Contreras-Félix & Francke, 2014: figs. 8–10). The OMP appears the most prominent in *V. coalcoman*, although the image is difficult to discern. In the other species, the OMP is quite subtle, appearing more as a slight reduction of the lamina inner edge due to a modest basal constriction. Unlike in *Kovarikia* (see Figs. 2 and A-4), the OMP does not form a conspicuous hook in any of these species. Therefore, we do not consider the OMP to be homologous to the secondary lamellar hook described herein.

Mating plug. Only a few mating plugs have been described for genera *Kovarikia* and *Pseudouroctonus*. Mating plugs have been illustrated for *P. sprousei* and *P. reddelli* (Francke & Savary, 2006: figs. 18, 21), *P. minimus castaneus* and *K. williamsi* (Soleglad & Fet, 2008: Figs. 87, 88), *P. savvasi* (Francke, 2009: fig. 4), and *P. peccatum* (Tate et al. 2013: fig. 17). Herein we present the first description of a mating plug from *K. bogerti* (see Appendix, Fig. A-4).

Diagnostic for the two *Kovarikia* mating plugs presently known (*K. williamsi* and *K. bogerti*) is its complicated base and unique crescent-shaped smooth edged barb. In Figure 2 we illustrate six different perspectives of the mating plug of *K. williamsi* in order to ascertain its structure (note, four perspectives of *K. bogerti* are illustrated in the Appendix, Fig. A-4). The barb is somewhat large and crescent-shaped. Its edge, which points towards the dorsal side when embedded in the hemispermatophore, is smooth. The external extremities of the barb are elongated and considerably

Figure 4: Pedipalp patella (right) external median (*EMc*) carina in *Kovarikia* species showing a *secondary* median carina. **Left.** *Kovarikia bogerti*, male, Palomar Mountain Road, San Diego Co., California, USA. **Center.** *Kovarikia williamsi*, male, Santa Ysabel Preserve, San Diego Co., California, USA. **Right.** *Kovarikia angelena*, male, Yerba Buena Canyon, Ventura Co., California, USA. Note, trichobothria *et₂*, *em₁*, *esb₂*, and *eb₃* are located between the two external carinae.

curved, contributing to its crescent-shaped appearance. The stock is relatively short when compared to the large barb. The mating plug base is quite complicated. Viewing it from the external perspective (i.e., where the "bottom" of the base is visible, blocking most of the stock and barb), two lobes are visible, their point of connection and edges somewhat sclerotized. From the internal view, the barb is visible on "top" and two the larger lobes are still visible. Separating the barb and stock and the two external lobes, is a larger irregularly shaped median lobe which is visible in all views and shows little sclerotization.

In Figure 3 we show two post-insemination mating plugs embedded in genital aperture of a female *K. williamsi*. This scorpion was found in a pitfall trap.

Pedipalp patella

A secondary exteromedian (*EM$_c$*) carina is present on the patella of all three *Kovarika* species (see Fig. 4). This carina is positioned inline with the primary *EM$_c$* on the dorsal half of the segment. Though this carina is as strongly granulated and continuous as the primary carina, it is not as well developed, not extending the entire length of the segment. Distally it begins approximately at the *et₂* trichobothrium and terminates basally at *eb₃*. Interestingly, trichobothria *et₂*, *em₁*, *esb₂*, and *eb₃* are located between these two external carinae on all three species of *Kovarikia*.

This carina is not present in *Pseudouroctonus* or *Uroctonites* (based on nineteen species examined).

Telson

Vesicular ridges. Gertsch & Soleglad (1972: figs. 122–126) illustrated the unusually shaped telson vesicles for the three species of *Kovarikia*. In these illustrations as well as in our Figure 5, the anterior base of the ventral aspect of the vesicle is swollen at the vesicle/aculeus juncture, thus visible from a dorsal or ventral perspective. Ventrally, two well-defined grooves are present along the vesicle, terminating at the vesicular ridges.
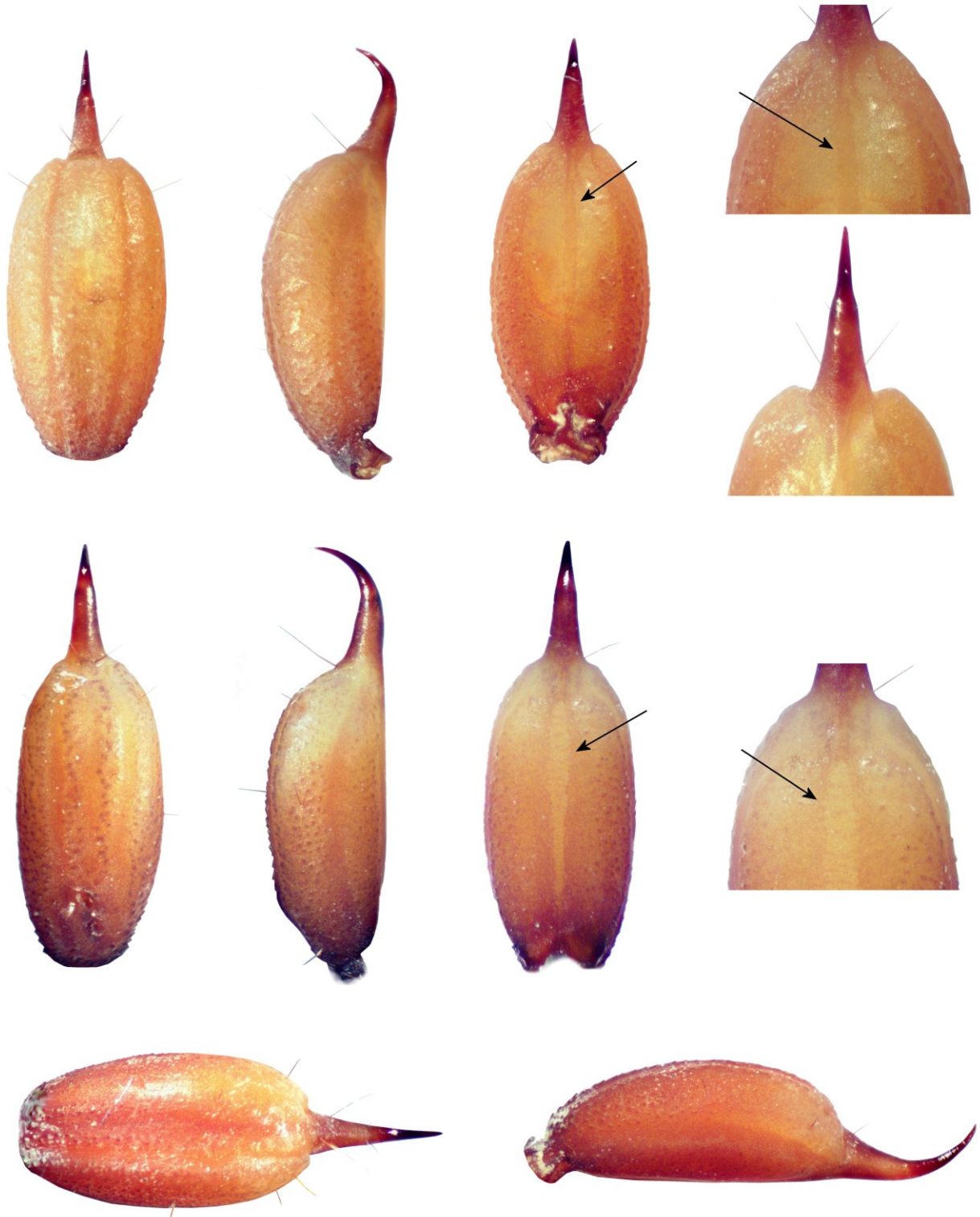
Figure 5: Telson morphology of genus *Kovarikia*. **Top.** *K. angelena*, male, Yerba Buena Canyon, Ventura Co., California, USA, ventral, lateral, and dorsal full views, and two closeup views of dorsal vesicle/aculeus juncture. In the lower dorsal view, which emphasizes the vesicular ridges, the telson is slightly tilted with the aculeus closer to the viewing plane. **Center.** *K. bogerti*, male, Palomar Mountain Road, San Diego Co., California, USA, ventral, lateral, and dorsal full views, and closeup view of dorsal vesicle/aculeus juncture. **Bottom.** *Kovarikia williamsi*, female, Santa Ysabel Preserve, San Diego Co., California, USA., ventral and lateral full views. Arrows point to the *linear patch* area on the vesicle. Note the *subaculear setal pair* is located at the base of the aculeus in all three species.
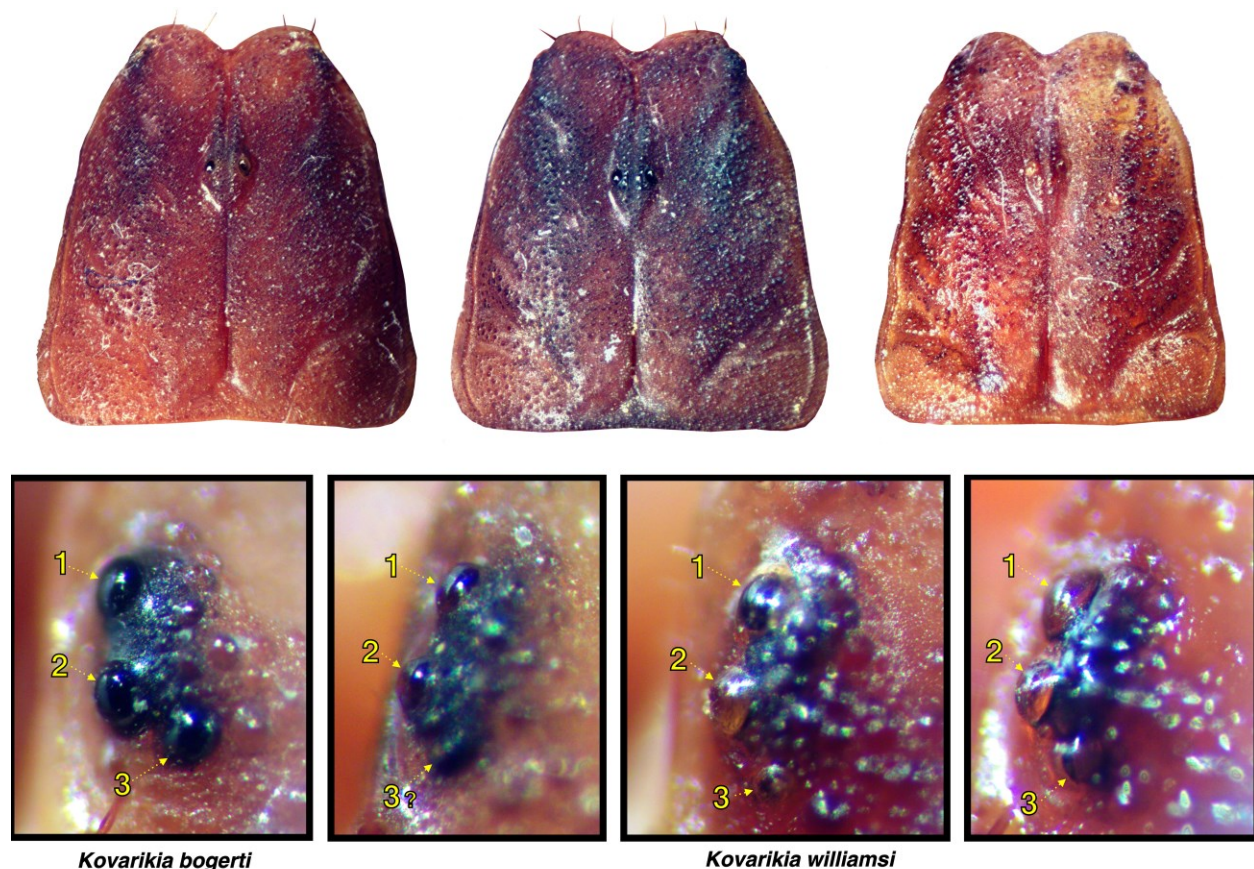
Figure 6: Carapace morphology of genus *Kovarikia*, **gen. nov.,** illustrating the deep anterior median indentation and the distally placed median eyes. **Top-Left.** *Kovarikia williamsi*, female, Santa Ysabel Preserve, San Diego Co., California, USA. **Top-Center.** *K. bogerti*, female, Old Mission Dam, San Diego Co., California, USA. **Top-Right.** *K. angelena*, male, Yerba Buena Canyon, Ventura Co., California, USA. **Bottom.** Lateral eye morphology. Arrows indicate two to three eyes, the most posterior eye either present, reduced in size, or essentially obsolete.

Based on this expansion of the vesicle, it abruptly narrows to the aculeus. Laterally, the abrupt tapering is not as well defined. The vesicular ridges, visible from either the dorsal or ventral perspective are the most defined for *K. williamsi* and *K. angelena*, in *K. bogerti*, the vesicular ridges are less defined and do not extend beyond the vesicle base.

Interestingly, the swollen vesicle with its ridges is not limited to the male, but is found in both genders. Usually, in many chactoids, the swollen telson vesicle is found in sexually mature males, indicating sexual dimorphism. Examples of this sexual dimorphism include *Anuroctonus* (Chactidae) and *Euscorpius* (Euscorpiidae).

Vesicular linear patch. On adult male specimens, a narrow linear smooth patch is present on the dorsal surface of the vesicle, extending from the base of the aculeus to most of the vesicle's length (pers. com. G. Lowe). The function of this dimorphic character is unknown. We illustrate this patch for two *Kovarikia* species in Fig. 5.

Subaculear setal pair. The position of the subaculear setal pair on the aculeus base represents another diagnostic character for *Kovarikia*. In other vaejovids, the subaculear setal pair usually occurs on the vesicle just before the aculeus juncture (for example, see Gertsch & Soleglad (1972: figs. 128–129, 132, 143, 146, 149, 150) and Soleglad & Fet (2008: figs. 170–181)). We suspect that the configuration of the swollen vesicle, its ridges, and the abruptly formed aculeus caused this unique shift in the position of the subaculear setal pair. A similar situation occurs with the iuroid genera *Calchas* and *Neocalchas* (Iuridae), as the former has a swollen vesicle, an abruptly tapered aculeus, and the subaculear setal pair positioned on the aculeus base (see Yağmur et al., 2013: fig. 8).

Other structures

Below we discuss additional, but less exclusive structures that collectively differentiate *Kovarikia*, but individually are not necessarily exclusive to the genus.
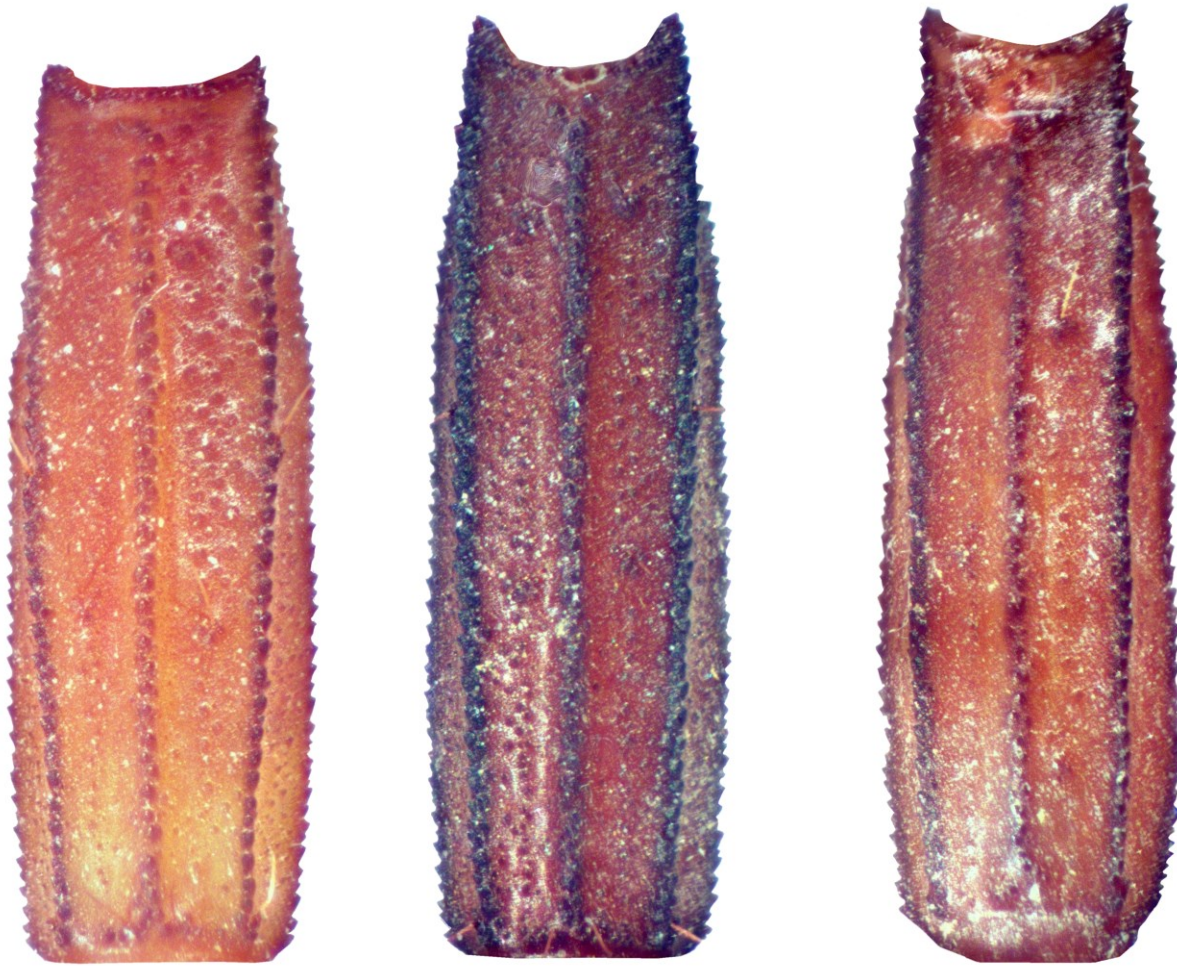
Figure 7: Metasoma segment V of genus *Kovarikia*, ventral view. **Left.** *Kovarikia williamsi*, male, Santa Ysabel Preserve, San Diego Co., California, USA. **Center.** *K. bogerti*, male, Palomar Mountain Road, San Diego Co., California, USA. **Right.** *K. angelena*, male, Yerba Buena Canyon, Ventura Co., California, USA.

Carapace. The carapace of *Kovarikia* is typical of that found in *Pseudouroctonus* with its conspicuous narrow, deep anterior indentation (see Fig. 6). The anterior indentation is quite deep in this genus, its depth as compared to the carapace length (averaged across the three carapaces shown in Figure 6) is 0.0603. For example, in the recently described *P. peccatum* Tate et al., 2013, the indentation ratio is 0.0443, roughly 36 % more shallow than that found in *Kovarikia*. Similarly, for three species of *Uroctonites* studied, the indentation ratio averaged 0.0414, 46 % more shallow.

Soleglad & Fet (2008: 51, figs. 126–127) presented three carapace-based morphometric ratios across the family Vaejovidae and demonstrated that the clade *Pseudouroctonus* + *Uroctonites* (nine species were represented) exhibited the smallest median eye tubercle, the smallest median eyes, and the most anteriorly advanced median eyes in the family. The three *Kovarikia* carapaces illustrated in this paper, when compared to the original histograms of Soleglad & Fet (2008), demonstrated the smallest median eyes, an average median eye tubercle width, and slightly less advanced median eyes.

Metasomal segment V. Tate et al. (2013: tab. 2) presented a detailed contrast of important structures of all known *Pseudouroctonus* species (including the three species now placed in *Kovarikia*). Their analysis included a comparison of the length/width ratio of metasomal segment V, and this feature is slender in all three species of *Kovarikia*. Only *P. reddelli* and its sister species *P. sprousei* have comparable or thinner segment V, in particular the latter where only the male is known. In Figure 7 the ventral views of metasomal segment V are illustrated for the three species of *Kovarika*. The calculated metasomal segment V length/width ratio ranges of these segments are as follows (based on Tate et al., 2013: Table 2) and additional data from this study:
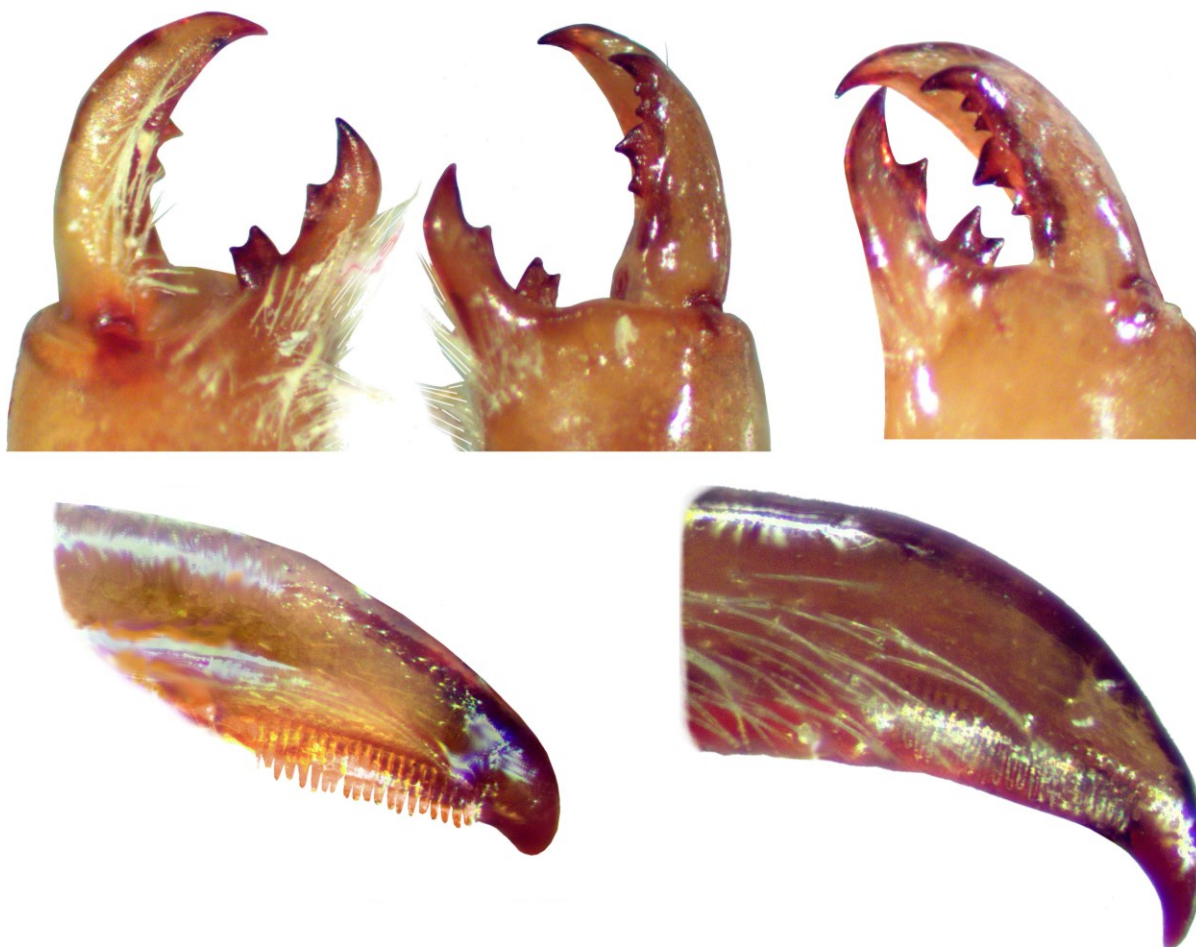
Figure 8: Representative chelicerae of genus *Kovarikia*. **Top-Left, Center.** Right chelicera, ventral and dorsal views. *Kovarikia williamsi*, female, Santa Ysabel Preserve, San Diego Co., California, USA. **Top-Right.** Right chelicera, dorsal view. *K. bogerti*, male, Palomar Mountain Road, San Diego Co., California, USA. **Bottom.** Ventral view of movable finger ventral edge (partial) showing the development of the serrula for *K. williamsi* and *K. bogerti* (same localities as stated above).

  K. angelena: ♂ 3.059–3.170, ♀ no data.
  K. bogerti: ♂ 3.087–3.444, ♀ 3.091–3.333
  K. williamsi: ♂ 3.130–3.400, ♀ 3.093–3.400

Based on the above data, the metasomal segment V in *Kovarikia* is generally three times longer than wide in both genders.

   Chelicerae. The cheliceral dentition of *Kovarikia* is typical of most vaejovines: it has two subdistal denticles (*sd*) on the movable finger dorsal edge, the ventral edge of the movable finger is smooth, and the ventral surface of the fixed fingers lacks denticles or tubercles. The serrulae are well-developed, exceeding 20 tines each. The lack of dentition/protuberances on the ventral surface of the fingers is partially diagnostic for *Kovarikia*, since they occur in several species in *Pseudouroctonus*.

   Pectinal tooth counts. The pectinal tooth counts found in *Kovarikia* are somewhat large when compared

to most *Pseudouroctonus* species. Only *P. peccatum*, *P. reddelli* and *P. sprousei* exhibit larger counts. In *P. cazieri*, pectinal tooth counts are roughly the same as in *Kovarikia*. The four *Uroctonites* species have lower pectinal tooth counts, ranging 7–10 in females and 8–10 in males. See Tate et al. (2013: tab. 2).

   Due to the apparent rarity of this genus, the number of specimens available is somewhat small. Our pectinal tooth statistics is based on the material examined, data supplied by G. Lowe, and data presented in Gertsch & Soleglad (1972: tables 3–4).

K. angelena: ♂ 10–12 (11.100) (±0.568) [10], ♀ 9–11 (10.100) (±0.568) [10]
K. bogerti: ♂ 13–14 (13.250) (±0.500) [4], ♀ 11–12 (11.571) (±0.535) [7]
K. williamsi: ♂ 13 (13.000) (±0) [6], ♀ 11–12 (11.688) (±0.479) [16]

	K. angelena	*K. bogerti*	*K. williamsi*	
	Yerba Buena Canyon, Ventura Co., California, USA	Palomar Canyon, San Diego Co., California, USA	Santa Ysabel Preserve, San Diego Co., California, USA	
	Male	Male	Male	Female
Total length	42.85	44.80	-	50.70
Carapace length	5.40	6.10	6.35	6.70
Mesosoma length	8.85	11.00	13.70	18.45
Metasoma length	22.00	21.50	22.05	19.60
Segment I length/width	2.90/2.80	2.90/2.65	2.95/2.65	2.60/2.65
Segment II length/width	3.40/2.70	3.35/2.50	3.45/2.60	3.00/2.65
Segment III length/width	3.60/2.55	3.60/2.35	3.80/2.50	3.25/2.35
Segment IV length/width	4.65/2.35	4.55/2.20	4.65/2.40	4.10/2.20
Segment V length/width	7.45/2.35	7.10/2.30	7.20/2.30	6.65/2.15
Telson length	6.60	6.20	-	5.95
Vesicle length	4.80	4.45	-	4.00
width/depth	2.60/2.10	2.15/1.90	-/-	2.15/1.65
Aculeus length	1.80	1.75	-	1.95
Pedipalp length	20.75	21.55	22.35	22.45
Femur length/width	5.20/1.85	5.70/1.85	5.90/2.10	6.05/2.05
Patella length/width	5.15/2.15	5.50/2.25	5.70/2.50	5.70/2.50
Chela length	10.40	10.35	10.75	10.70
Palm length	5.70	5.65	5.95	5.65
width/depth	2.85/3.95	2.90/4.00	3.30/4.75	3.00/4.05
Fixed finger length	4.00	4.15	4.25	4.10
Movable finger length	5.40	5.60	5.70	5.55
Sternum length/width	1.40/1.60	1.55/1.75	1.75/1.75	1.75/1.80
Pectines teeth	10/11	13/13	13/13	12/12
middle lamellae	-/-	7/7	7/7	7/6

Table 1: Morphometrics (mm) of genus *Kovarikia*, **gen. nov**.

As generally characteristic of *Pseudouroctonus* and *Uroctonites*, the relative number of pectinal teeth in *Kovarikia* when compared to the adult size is small, the total length / median tooth count ratio ranges 3.259–4.640 for adult males. See Soleglad & Fet (2008: 69–71) for comparisons with other vaejovids.

Systematics

Order **SCORPIONES** C. L. Koch, 1850
Suborder Neoscorpiones Thorell et Lindström, 1885
Infraorder Orthosterni Pocock, 1911
Parvorder Iurida Soleglad et Fet, 2003
Superfamily Chactoidea Pocock, 1893
Family Vaejovidae Thorell, 1876
Subfamily Vaejovinae Thorell, 1876

Genus *Kovarikia* Soleglad, Fet et Graham, gen. nov.
Figures 1–9
http://zoobank.org/urn:lsid:zoobank.org:act:4DFE47 A9-A7EF-4D0D-A6C1-7A44A6A1B3A9

Type Species. *Kovarikia williamsi* (Gertsch et Soleglad, 1972), **comb. nov.** [=*Pseudouroctonus williamsi* (Gertsch et Soleglad, 1972)], designated here.

Composition. This genus contains three species, *K. williamsi*, **comb. nov.** [=*Pseudouroctonus williamsi* (Gertsch et Soleglad, 1972)], *K. bogerti*, **comb. nov.** [=*Pseudouroctonus bogerti* (Gertsch et Soleglad, 1972)], and *K. angelena*, **comb. nov.** [=*Pseudouroctonus angelenus* (Gertsch et Soleglad, 1972)].

Figure 9: *Kovarikia williamsi*, adult male, collected in May of 2009 from a rock crevice at Mission Trails Regional Park, San Diego Co., California, USA.

Figure 10: Habitats of select *Kovarikia* species. **Left.** *Kovarikia williamsi*, general habitat and closeup of rock fissures where several specimens were found. Misson Trails, San Diego Co., California, USA, **Right.** *K. bogerti*, general habitat, Palomar Mountain, San Diego Co., California, USA.

Distribution. Found in southern California, USA, including Los Angeles, Ventura, San Bernardino, Riverside, and San Diego Counties. See map in Figure 11.

Diagnosis. Neobothriotaxy is found on the chelal ventral surface, numbering 1–2 accessory trichobothria. Hemispermatophore equipped with a secondary lamellar hook; mating plug possesses a large crescent-shaped smooth edged barb. Secondary exteromedian (*EM$_c$*) carina present on the pedipalp patella. Telson vesicle swollen with ventral ridges at the aculeus juncture; subaculear setal pair located on base of the aculeus. Cheliceral movable and fixed fingers lack dentition and/or protuberances on their ventral surfaces. Ventral surface of leg tarsus with 2–3 distal spinule pairs. See Table 1 for measurements of these species.

Etymology. This genus (feminine in gender) is named in honor of our colleague and friend František Kovařík (Prague, Czech Republic) who has made significant contributions to scorpion systematics.

Key to Species of *Kovarikia*

1 – Chelal palm depth / palm length in male 0.693–0.708; chelal length / palm depth in male 2.588–2.633 ……………………………………………...…… **2**
■ – Chelal palm depth / palm length in male 0.798; chelal length / palm depth in male 2.263……………. …..…. *Kovarikia williamsi* **(Gertsch et Soleglad, 1972)**

2 – Vesicular ridges are well developed and protrude beyond the aculeus juncture; pectinal tooth counts of male 10–12…………………………………………… …….. *Kovarikia angelena* **(Gertsch et Soleglad, 1972)**
■ – Vesicular ridges are of medium development and do not protrude beyond the aculeus juncture; pectinal tooth counts of male 13–14…………………………… ……..... *Kovarikia bogerti* **(Gertsch et Soleglad, 1972)**

Discussion

   Kovarikia is clearly in the family Vaejovidae: the trichobothrial pattern of the chelal fixed finger *est–esb–*
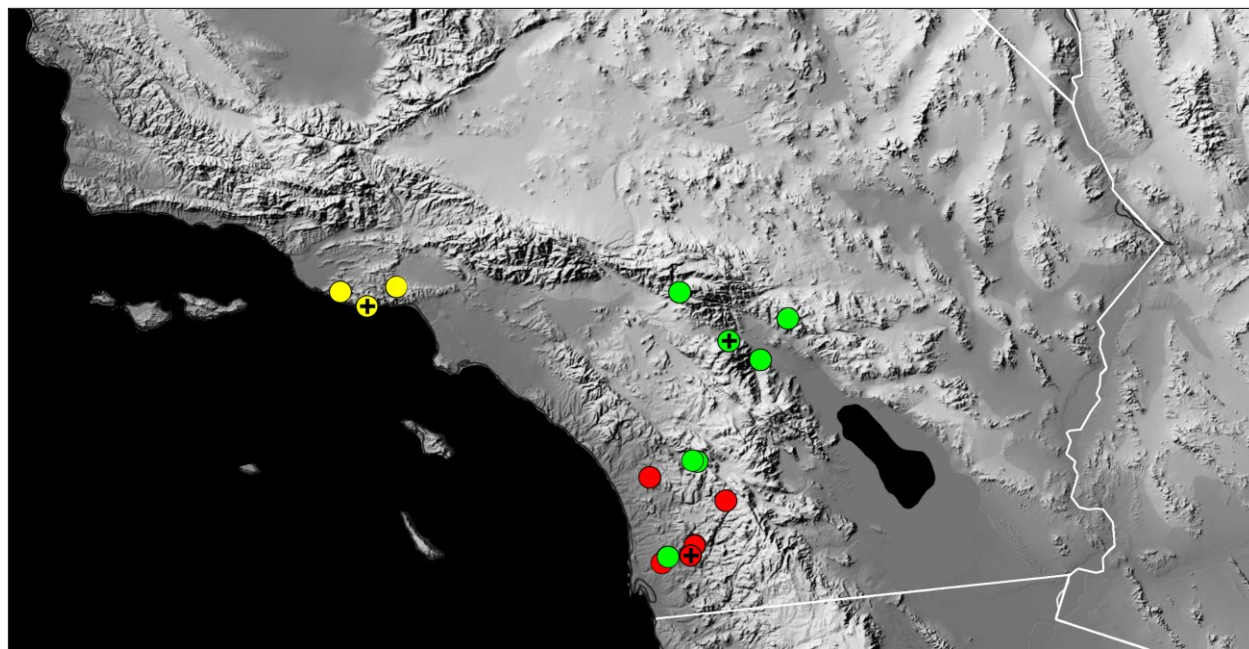
Figure 11: Map of southern California showing distribution of genus *Kovarikia*, **gen. nov.** *Kovarikia williamsi* = red icon, *K. bogerti* = green icon, *K. angelena* = yellow icon. Icons with '+' indicate type locality.

eb juncture angles towards the fixed finger edge, *eb* angles towards the dorsal edge; *ib–it* pair is located, in part, on the finger, not on the palm; V_1–V_4 series extends most of the palm length and V_1–V_2–V_3 juncture is straight, not angled towards the internal condyle; patellar trichobothrium v_3 is located on the external surface; chelal finger median (*MD*) denticle row groups are aligned in a straight line; inner accessory (*IAD*) and outer accessory (*OAD*) denticles are not present; genital operculum of the female is not separated its entire length, but instead is connected at least for the anterior half; the pedipalp patellar DPS_c carina is well developed; the terminus of the dorsolateral (*DL*) carina is flared, not coinciding with the articulation condyle. See Soleglad & Fet (2008: p. 74).

The clade *Uroctonites* + (*Kovarikia* + *Pseudouroctonus*) proposed here is based on the following shared characters. The chelae are stocky with swollen palms and are somewhat flat in appearance due to the weak to obsolete development of the dorsosecondary and ventromedian carinae (i.e., a major derivation). Chelal internal trichobothria *ib–it* are located basal on the fixed finger, trichobothrium *ib* sometimes occurring on the extreme distal aspect of the palm, adjacent to the movable finger membrane. The carapace exhibits a conspicuous anterior median indentation, and the median eyes are reduced in size and located considerably anterior of the carapace midpoint. The serrula are well developed and the pectinal tooth counts as compared to the scorpion's adult size are relatively small. The hemi-

spermatophore of the clade (*Kovarikia* + *Pseudouroctonus*) is similar to that found in other vaejovines whereas the hemispermatophore of *Uroctonites* exhibits several structural differences.

Within this clade, *Kovarikia*'s placement with *Pseudouroctonus* is quite straightforward (as compared to *Uroctonites*). The hemispermatophore lamina sides are sub-parallel (not tapered), the terminus is truncated (not pointed); lamellar hook is located distal of dorsal trough (not adjacent to), and terminus bifurcated (not intact). The mating plug is sclerotized (not partially gelatinous). Ventral setal pairs of the leg tarsus are irregularly positioned (not aligned); setae irregularly sized, but never stout (not the same size and stout).

The three species comprising *Kovarikia* are rare in collections. We know little about their natural history and the full extent of their geographic distribution is limited to what is shown in the map in Figure 11. Figures 9–10 show *K. williamsi* live and examples of its natural habitat.

Ecological Observations

Literature records and field observations (MRG pers. obs.) indicate that *Kovarikia* spp. are lithophiles, and thus restricted to rocky habitats in canyons adjacent to riparian areas throughout the foothills of southern California (Fig. 11). Most specimens have been discovered during the day under large, flat boulders. Like other scorpions, *Kovarikia* probably employ both active and ambush foraging behaviors (McCormick & Polis,

1990). For instance, *K. williamsi* has been observed both actively foraging a few meters away from boulders and ambushing prey items from within narrow rock crevices (MRG pers. obs.; see Fig. 10). *Kovarikia* spp. are more dorsoventrally flattened than most other vaejovid scorpions, so they may be adapted to living within the narrow fissures within rocks and thin gaps underneath large flat boulders. *Kovarikia* do not appear to burrow, but they do form narrow scrapes under large flat rocks and boulders, usually 10–20 cm from the edge (MRG pers. obs.).

Biogeography

Although there are limited occurrence records, *Kovarikia* appears to be distributed throughout the Transverse and Peninsular ranges of southern California and potentially northern Baja California, Mexico. Phylogeographic studies of co-occurring taxa in these areas indicate various levels of genetic differentiation among populations in the region. Several studies have uncovered major genetic discontinuities in the area between the Sierra Pelona and San Gabriel Mountains, which are referred collectively as the Transverse Range (TR) break. Interestingly, the TR lies in the region between *K. angelena* from the Santa Monica Mountains in the west and *K. bogerti* in the San Bernardino and San Jacinto Mountains to the east. Most authors attribute the TR break to a marine embayment of the Santa Clara River Valley during the Pliocene (Rodríguez-Robles et al., 1999; Spinks & Shaffer, 2005; Chatzimanolis & Caterino, 2007), but Phillipsen & Metcalf (2009) suggest that more recent events, such as Pleistocene climate fluctuations, could have severed gene flow in this region. Whatever the mechanism, future studies on the phylogeography of *Kovarikia* could prove useful in providing additional insight into the processes that generated the TR break.

To the south, the overlapping distributions of *K. bogerti* and *K. williamsi* are intriguingly similar to the distribution of haplotype groups from another riparian species, *Pseudacris cadaverina* (California treefrog). Specifically, *P. cadaverina* haplotypes form two monophyletic groups; one distributed throughout the eastern Transverse Ranges and extending into the very northern Peninsular Ranges (similar to *K. bogerti*), and one found in the Peninsular Ranges and just slightly extending into the southeastern Transverse Ranges (similar to *K. williamsi*) (Phillipsen & Metcalf, 2009: fig. 1). Vicariance in this region has been attributed to Pleistocene embayments of the Los Angeles Basin and simultaneous northward expansions of marine waters from the Gulf of California to the San Gorgonio Pass, an event referred to as the San Gorgonio constriction (Murphy, 1983). Although vicariance due to the San Gorgonio constriction was not statistically supported for *P.*

cadaverina, Phillipsen & Metcalf (2009) suggest that a signal of vicariance could have been eroded by recent gene flow or incomplete lineage sorting. Therefore, the San Gorgonio constriction could have simultaneously sundered populations of multiple riparian taxa like *Kovarikia* and *P. cadaverina* during the Pleistocene. However, as an alternative hypothesis, recent studies suggest that stenotopic scorpions have had much longer histories with landscapes, with diversification more strongly tied to ancient (pre-Pliocene) changes in geomorphology (Bryson et al., 2013) and on small spatial scales (Habel et al., 2012). Thus, *Kovarikia* represents an ideal riparian taxon to explore these ideas using molecular techniques, and perhaps a chance to investigate ancient associations between organisms and geologic processes in southern California.

Acknowledgments

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Appendix A
Trichobothrial Patterns and Hemispermatophore of Select Species of *Kovarika*

This appendix contains the trichobothrial patterns of the three species of genus *Kovarikia* and the hemispermatophore and mating plug of *K. bogerti*.
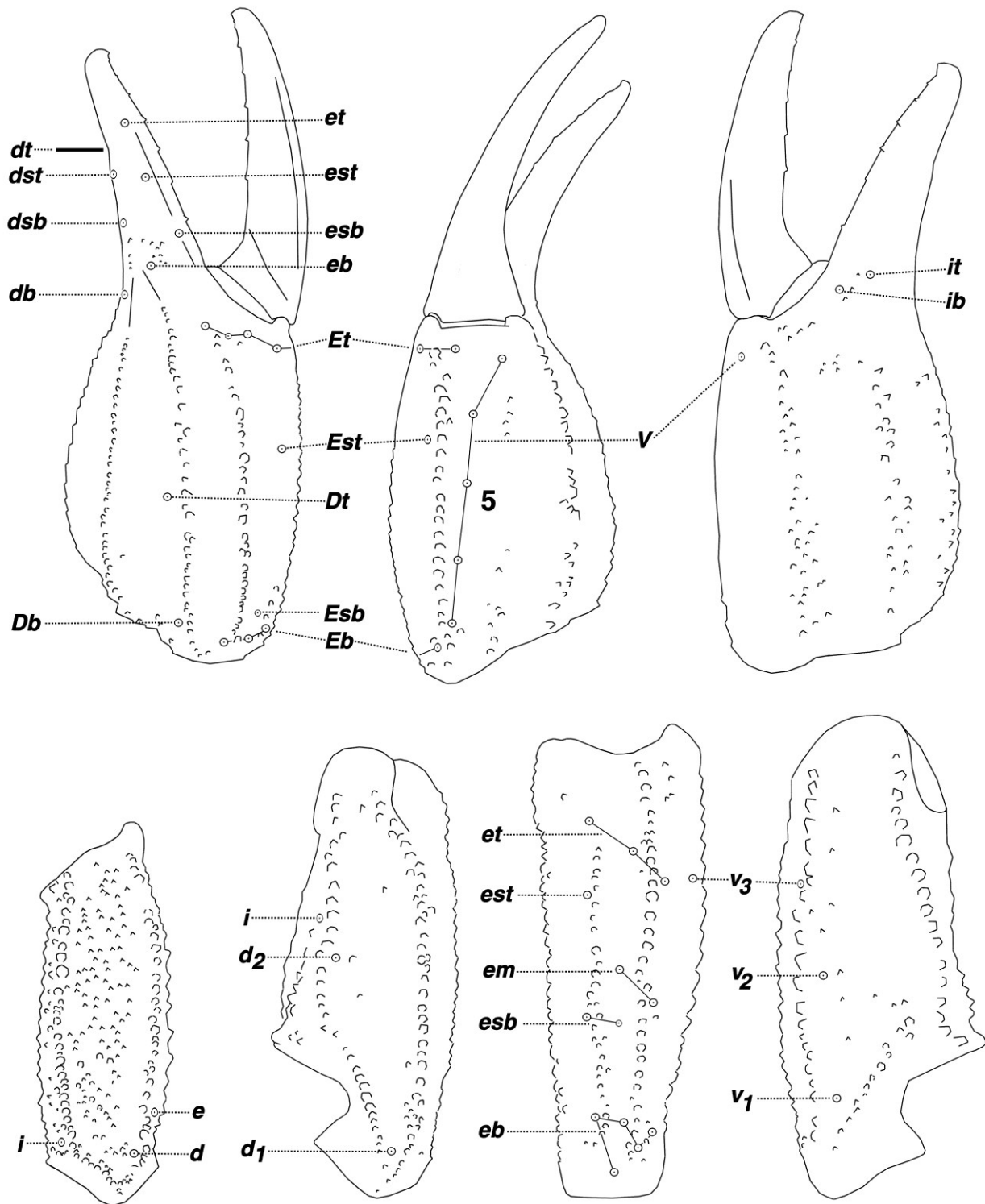
Figure A-1: *Kovarikia angelena*, male, Yerba Buena Canyon, Ventura Co., California, USA. Trichobothrial pattern. Note neobothriotaxy occurs on the ventral surface of the chela, exhibiting one accessory trichobothrium, a total of five trichobothria.
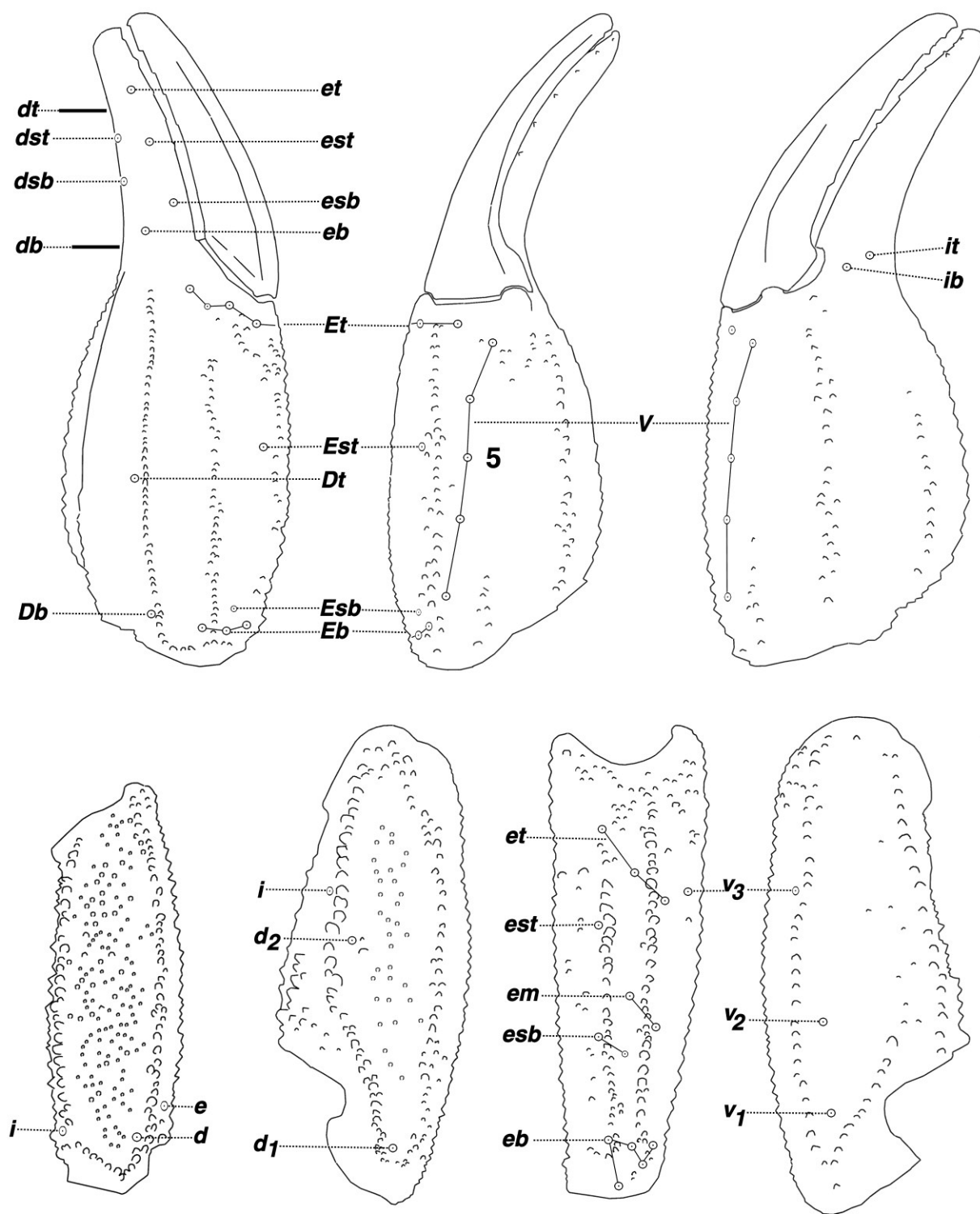
Figure A-2: *Kovarikia bogerti*, male, Palomar Mountain Road, San Diego Co., California, USA. Trichobothrial pattern. Note neobothriotaxy occurs on the ventral surface of the chela, exhibiting one accessory trichobothrium, a total of five trichobothria.
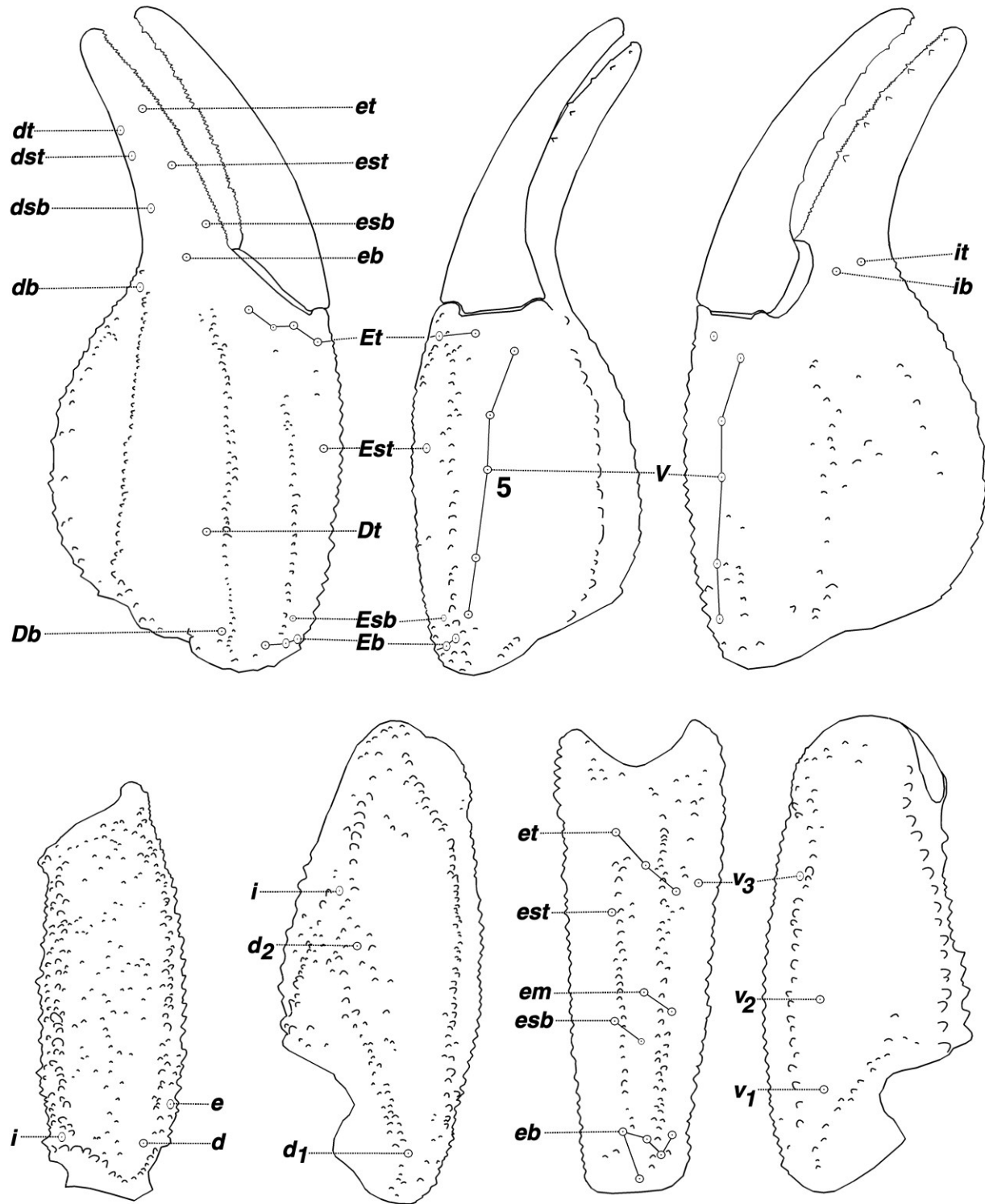
Figure A-3: *Kovarikia williamsi*, male, Santa Ysabel Reserve, San Diego Co., California, USA. Trichobothrial pattern. Note neobothriotaxy occurs on the ventral surface of the chela, exhibiting one accessory trichobothrium, a total of five trichobothria.
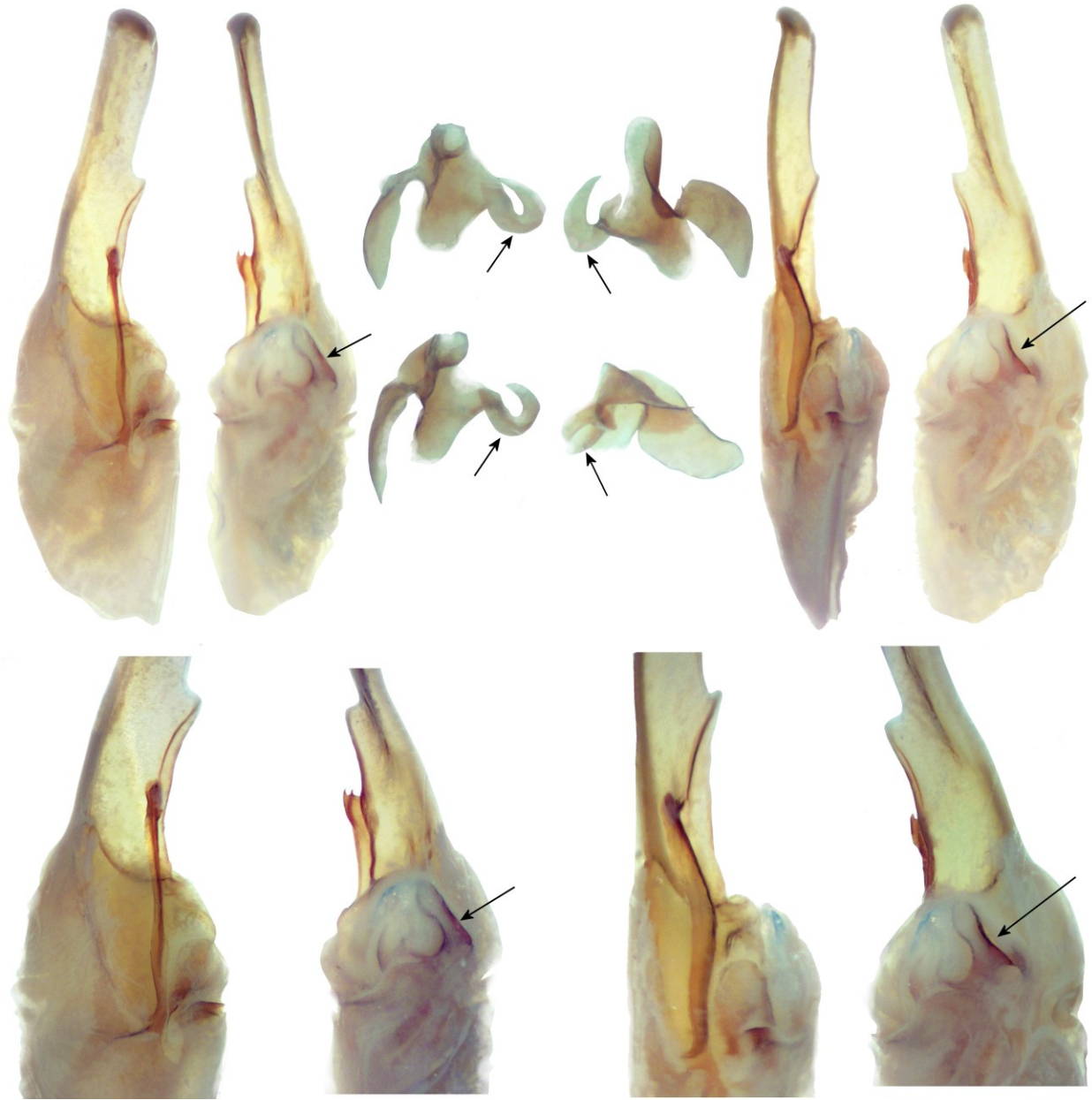

Figure A-4: *Kovarikia bogerti*, Palomar Mountain Road, San Diego Co., California, USA. Right hemispermatophore (photographed submerged in alcohol). **Upper Left.** Complete structure, dorsal and interoventral views. **Upper Right.** Complete structure, internal and ventral views. **Lower.** Closeup of median area, dorsal, interoventral, internal, and ventral views, showing the construction of the lamellar hook. **Upper Center.** Mating plug, dorsal and ventral views (top), and dorsal and interoventral views (bottom). Note the crescent-shaped barb with a smooth edge (indicated by arrows). The mating plug, embedded in the median area, is visible in the interoventral and ventral views (indicated by arrows).